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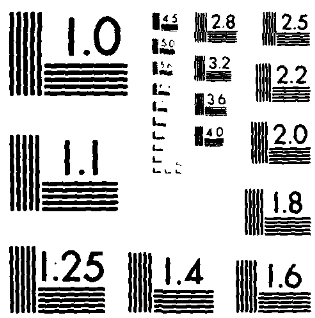


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AEDC-TSR-81-V37



# FLOW FIELD INVESTIGATIONS OF A SIMULATED WEAPONS CAVITY AT MACH 3

W. A. Crosby

Calspan Field Services, Inc.

November 1981

Final Report for Period 27 October 1981

Approved for public release; distribution unlimited.





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J. T. Best

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John M. Rampy

JOHN M. RAMPY, Director
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Flow field investigations of a simulated weapons cavity were performed at Mach 3 in the von Karman Facility Supersonic Tunnel A. Surface pressure measurements, cavity acoustic environment, and flow field pressure and temperature data were obtained on various cavity configurations. Included were studies of suppression fence height and simplified store sizes in an open-sided cavity with length-to-depth ratio of 2.25.

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APPENDIXES

I. ILLUSTRATIONS



II. TABLES



III. SAMPLE TABULATED DATA

## NOMENCLATURE

| | |
|---|---|
| A | Cavity acoustic data-type |
| ALPHAC | Cavity model angle of attack or CTS pitch drive, deg |
| ALPHAP | Probe angle of attack, deg |
| CODE | Model configuration number |
| CONFIG | Model configuration designation |
| DPP | Pitch plane cone probe differential pressure, PCS1-PCS3, psia |
| DPY | Yaw plane cone probe differential pressure, PCS2-PCS4, psia |
| ETAC | CTS aft yaw drive, deg |
| FENCE | Suppression fence height in percent of estimated boundary layer thickness ($\delta$ = 0.468 in.) |
| GRID | A predetermined set of probe positions used to command the CTS motion in computer control |
| M | Free-stream Mach number |
| MC | Computed cone probe Mach number |
| MP | Computed rearward-facing pitot probe Mach number |
| P | Free-stream static pressure, psia or probe data-type |
| PCSi | Cone probe static pressures, i=1-4, psia |
| PCSA | Average cone probe static pressure, psia |
| PCT | Cone probe total pressure, psia |
| PHICB | CTS roll drive, deg |

| | |
|---|---|
| PHIP | Probe roll angle, deg |
| PN | Data point number |
| PPT | Rearward-facing probe total pressure, psia |
| PT2 | Stagnation pressure downstream of a normal shock, psia |
| PT | Tunnel stilling chamber pressure, psia |
| PW | Cavity static pressure data-type |
| Q | Free-stream dynamic pressure, psia |
| RE | Free-stream unit Reynolds number, $ft^{-1}$ |
| RUN | Data set identification number |
| STORE | Percent of cavity cross section area occupied by store shape (total area = 36 $in.^2$) |
| T | Free-stream static temperature, °R |
| Txxx | Cavity static pressure tap number |
| TxxxA | Cavity acoustic pressure tap number |
| TPT | Total temperature probe temperature, °R |
| TRIP | Boundary layer trip size, in. |
| TT | Tunnel stilling chamber temperature, °R |
| X | Axial drive position, in. |
| XC | CTS axial drive, in. |
| XO | Cavity model axial coordinate, positive aft from model leading edge, in. |
| XPC,XPP,XPT | Axial position of cone, pitot, and temperature probes, respectively, from cavity model leading edge, in. |

| | |
|---|---|
| Y | Lateral drive position, in. |
| YAWC | Cavity model yaw angle or CTS forward yaw drive, deg |
| YAWP | Probe yaw angle, deg |
| YO | Cavity model lateral coordinate, positive right (looking upstream) from model centerline, in. |
| YPC,YPP,YPT | Lateral position of cone, pitot, and temperature probe, respectively, from cavity model centerline, in. |
| Z | Vertical drive position, in. |
| ZC | CTS vertical drive, in. |
| ZO | Cavity model vertical coordinate, positive up from the top of cavity, in. |
| ZPC,ZPP,ZPT | Vertical position of cone, pitot, and temperature probes, respectively, from the top of the cavity, in. |
| $\delta$ | Theoretically estimated turbulent boundary layer thickness, in. |

## 1.0 INTRODUCTION

The work reported herein was performed by the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), under Program Element 61101F, Control Number 0100, at the request of Air Force Weapons Laboratory (AFWL), Kirtland Air Force Base, New Mexico 87117. The AFWL/NTSAC project manager was Mr. J. W. Doran. The results were obtained by Calspan Field Services, Inc./AEDC Division, operating contractor for the Aerospace Flight Dynamics testing effort at the AEDC, AFSC, Arnold Air Force Station, Tennessee. The test was performed in the von Karman Gas Dynamics Facility (VKF) Supersonic Tunnel A on 27 October 1981, under AEDC Project number C146VA.

The test objective was to provide experimental data to support verification of Lockheed General Interpolants Method (GIM) computer code for two-dimensional flow in a simulated weapons cavity.

Testing was accomplished at Mach 3, Reynolds number $3.0 \times 10^6$ $ft^{-1}$ at zero incidence to the free-stream. Vertical flow-field surveys were made forward, aft, and within the cavity utilizing a probe mounted on the VKF Captive Trajectory System (CTS). The instrumented cavity length-to-depth ratio was 2.25. Data were obtained on configurations of varying store sizes (relative to cavity cross section area) and suppression fence height. Photographic data were obtained at all test data points. Expected cavity wave motion was not detectable either acoustically or optically during the test. However, a subsequent review of the high speed schlieren (4000 fps) movies obtained indicates that a typical cavity wave motion was present.

All test data have been transmitted to the sponsor/user as described in Table 1. Inquiries to obtain copies of the test data should be directed to AFWL/NTSAC, Kirtland Air Force Base, NM 87117. A microfilm record of the tabulated data has been retained in the VKF at AEDC.

## 2.0 APPARATUS

### 2.1 TEST FACILITY

Tunnel A (Fig. 1) is a continuous, closed-circuit, variable density wind tunnel with an automatically driven flexible-plate-type nozzle and a 40- by 40-in. test section. The tunnel can be operated at Mach numbers from 1.5 to 6 at maximum stagnation pressures from 29 to 200 psia, respectively, and stagnation temperatures up to 750°R at Mach number 6. Minimum operating pressures range from about one-tenth to one-twentieth of the maximum at each Mach number. The tunnel is equipped with a model injection system which allows removal of the model from the test section while the tunnel remains in operation. A description of the tunnel and airflow calibration information may be found in the Test Facilities Handbook*.

*Test Facilities Handbook (Eleventh Edition). "von Karman Gas Dynamics Facility Vol. 3" Arnold Engineering Development Center, June 1979.

## 2.2 TEST ARTICLE

The test article (Fig. 2) was a simulated weapons cavity of length-to-depth ratio 2.25 cut out from a flat-top wedge designed and fabricated at AEDC. The stainless steel model was instrumented with 40 static pressure orifices and five acoustic microphones (Table 2). The static pressure orifices were arranged in 5 rays to obtain cross flow pressure distribution. The cavity was located 30.0 in. from the flat plate leading edge. The rear wall was situated 9.0 in. downstream of the cavity edge. A boundary layer trip consisting of a Carborundum™ grit (#60, 0.0160 in. height) strip 0.25 in. wide was located 1.5 in. from the leading edge to induce transition of the boundary layer. Model configuration variables included suppression fences and simple store shapes. Interchangeable fences (Fig. 2d) of 0.0, 0.5, and 1.0 boundary layer thickness were provided (boundary layer thickness, $\delta$, was estimated as 0.47 in.). The 0.5 $\delta$ fence was not used. Simplified store shapes (Fig. 3) with pylon attachments were built corresponding to 25, 50, and 75 percent of the total cavity cross-section area (36.0 in.$^2$). The 75 percent store was not used. The baseline configuration was the empty cavity without the fence.

Flow field surveys were made using the probes shown in Fig. 4. The probes mounted on the CTS consisted of a 5-hole Mach number/flow angularity 20 deg half-angle cone probe, an unshielded Chromel®-Alumel® total temperature probe, and a 0.093 in. OD rearward facing Mach number pitot probe. Details of the cone probe are provided in Fig. 5.

An installation sketch of the model in Tunnel A is provided in Fig. 6, and an installation photograph is shown in Fig. 7.

## 2.3 TEST INSTRUMENTATION

The cavity model was instrumented with 40 surface static pressure taps longitudinally spaced in 0.5 in. (or greater) increments on five lateral rays. The lateral rays were required to check for three dimensional flow effects. The primary instrumentation ray was along the model centerline. In addition, five dynamic pressure transducers were located in the cavity model and used to record acoustic environment and average cavity sound pressure level. Model angle of attack was set to zero as indicated by an on-board inclinometer.

The flow field probe (details provided in Section 2.2) was mounted on the VKF Captive Trajectory System (CTS). The CTS* consists of a model support with electro-mechanical drive systems for six degrees of freedom and is attached to the top of the tunnel as shown in the conceptual drawing given in Fig. 8. The axial and vertical motions (XC and ZC) are obtained using linear drive units while lateral motion is achieved by rotating the roll-pitch-yaw support arm about the vertical support axis with the aft yaw mechanism (ETAC) and compensating for the resulting yaw with the forward yaw mechanism (YAWC). The forward yaw

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*Billingsley, J. P., Burt, R. H., and Best, J. T. "Store Separation Testing Techniques at the Arnold Engineering Development Center, Volume III: Description and Validation of Captive Trajectory Store Separation Testing in the von Karman Facility." AEDC-TR-79-1, March 1979.

and pitch (ALPHAC) motions are obtained through two knuckle joints with axes 90 deg to each other (the pitch axis is upstream of the yaw axis), and finally the most upstream motion of the system is the roll (PHICB). Only the axial, vertical, and pitch motions were required to achieve the test objectives. The excursion bands and rates of travel of the CTS drives are given in Table 3. The measuring devices, recording devices, calibration methods, and estimated measurement uncertainties of the six degree of freedom motions of the CTS are given in Table 4.

The measuring devices, recording devices, and calibration methods used for all other measured parameters are also listed in Table 4 along with their estimated measurement uncertainties.

Model flow-field photographs were obtained using the VKF Tunnel A double-pass optical flow visualization system. Color schlieren 70mm stills were made using this system at all test data points. High speed (4000 fps) 16 mm color schlieren movies were obtained on each configuration without the influence of the probe. A video cassette recording of the entire test was also made with this system.

# 3.0 TEST DESCRIPTION

## 3.1 TEST CONDITIONS

A summary of the nominal test conditions is given below.

| M | PT, psia | TT, °R | Q, psia | P, psia | RE x $10^{-6}$/ft |
|---|---|---|---|---|---|
| 3.0 | 18.8 | 530 | 3.201 | 0.505 | 3.0 |

At some test conditions, particularly at sub-atmospheric stagnation pressures, the air humidity level affects the test section Mach number. The Tunnel A sidewall Mach number probe is used periodically when testing at these conditions to monitor deviations from the standard calibrated Mach numbers. When a deviation is measured, the free-stream conditions are corrected and the actual Mach number is printed on the data tabulations.

A test summary showing all configurations tested and the variables for each is presented in Table 5.

## 3.2 TEST PROCEDURES

### 3.2.1 General

For CTS tests in the VKF continuous flow wind tunnels (A, B, C), the parent (cavity) model is mounted on a sting support mechanism in an installation tank directly underneath the tunnel test section. The tank is separated from the tunnel by a pair of fairing doors and a safety door.

When closed, the fairing doors, except for a slot for the pitch sector, cover the opening to the tank and the safety door seals the tunnel from the tank area. After the parent model is prepared for a data run, the personnel access door to the installation tank is closed, the tank is vented to the tunnel flow, the safety and fairing doors are opened, the model is injected into the airstream, and the fairing doors are closed. The parent model was leveled to zero angle of attack and the data obtained. After this, the sequence is reversed and the tank is vented to atmosphere to allow access to the model in preparation for the next data set. The sequence is repeated for each configuration change. Flow field probe attitude and positioning and data recording were accomplished using the CTS in the grid mode of operation. The grid matrices, which are tables of model attitude and position, were loaded into the VKF DEC 10 computer prior to the test. During the test, the required grid was selected and the positioning of the model was controlled by the computer which automatically recorded all the data inputs at each grid point location. Grid survey stations are shown in Fig. 9. Vertical probe surveys were accomplished by driving the CTS in 0.250 in. increments when inside the cavity and in 0.125 in. increments when the probe centerline was at or above Z0 = 0.00 in. Probe centerline was typically 0.250 in. (0.336 in. for 50 percent store) above the model or store surface at the initiation of the survey. All vertical surveys were terminated 1.125 in. above the top of the cavity. The process was repeated until the grid matrix was completed. The data recording for the cavity model was accomplished using the tunnel data acquisition system which was also automatically controlled by the computer.

Initial alignment of the probe and cavity model was achieved through a "touch" docking technique utilizing the CTS electrical grounding circuit. Once the cavity model was leveled the probe was moved to precision wind-off alignment positions. Axial location was checked optically with a scope and the probe driven vertically downward until contact was made with the cavity model, thus completing the ground loop circuit and stopping all drives. The probe was then raised 0.100 in. from the model surface using known linear drive potentiometer settings. Air-on docking positions were recorded such that subsequent dockings were repeated precisely.

### 3.2.2 Data Acquisition

As described in Section 3.2.1, data were taken in the grid mode of operation using the CTS and tunnel data systems. Data were obtained at predetermined values of probe positions. Dynamic pressure measurements in the cavity (without probe interference) were recorded on analog tape over a time period of 30 sec. Pressure data and probe position data utilized 1 and 10 samples, respectively, taken over a 1 sec time span.

## 3.3 DATA REDUCTION

Cavity model and probe pressure/temperature data were obtained utilizing the CTS data acquisition system as described in Section 3.2. Cavity surface static pressure data were normalized by free-stream static pressure. Cavity acoustic environment was converted to sound pressure level. Probe parameters were true readings. Cone probe differential pressures were also provided.

Cone-derived Mach number (MC) was evaluated by a technique developed at VKF for this probe and is described in AEDC-TR-80-52*. Rearward facing pitot probe Mach number was evaluated but was nominally zero.

Relative probe positions were given in inches referenced to the centerline point on the cavity model leading edge (Fig. 9).

### 3.4 UNCERTAINTY OF MEASUREMENTS

In general, instrumentation calibrations and data uncertainty estimates were made using methods recognized by the National Bureau of Standards (NBS)**. Measurement uncertainty is a combination of bias and precision errors defined as:

$$U = \pm (B + t_{95}S)$$

where B is the bias limit, S is the sample standard deviation, and $t_{95}$ is the 95th percentile point for the two-tailed Student's "t" distribution (95-percent confidence interval), which for sample sizes greater than 30 is taken equal to 2.

Estimates of the data uncertainties in the basic measurements of this test are given in Table 4a. Data uncertainties are determined from in-place calibrations through the data recording system and data reduction program.

Propagation of the bias and precision errors of measured data through the calculated data are made in accordance with the reference** below and the results are given in Table 4b.

## 4.0 DATA PACKAGE PRESENTATION

The data package contains tabulated cavity model and probe pressure data along with tunnel condition and position data. Sample tabulations are given in Appendix III.

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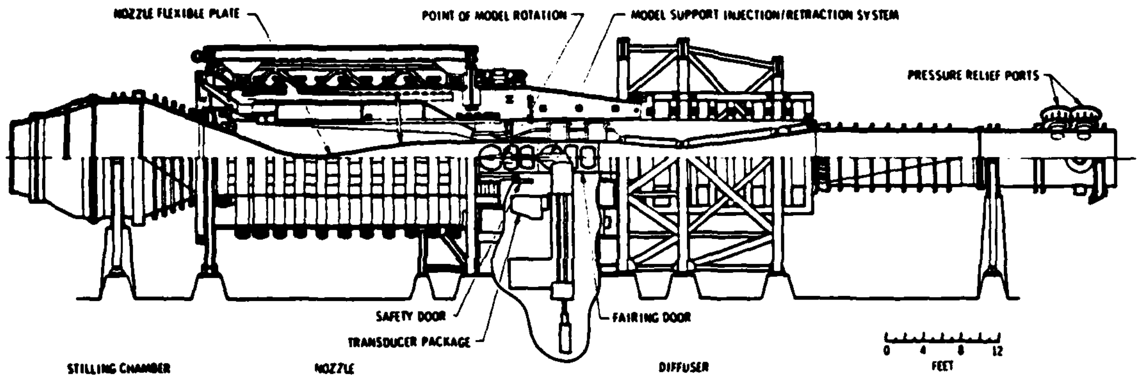
*Gray, J. D. and Billingsley, J. P. "Internal Drag Experiments for Data Correlation, ASALM PTV/TVV," AEDC-TR-80-52, May 1981.

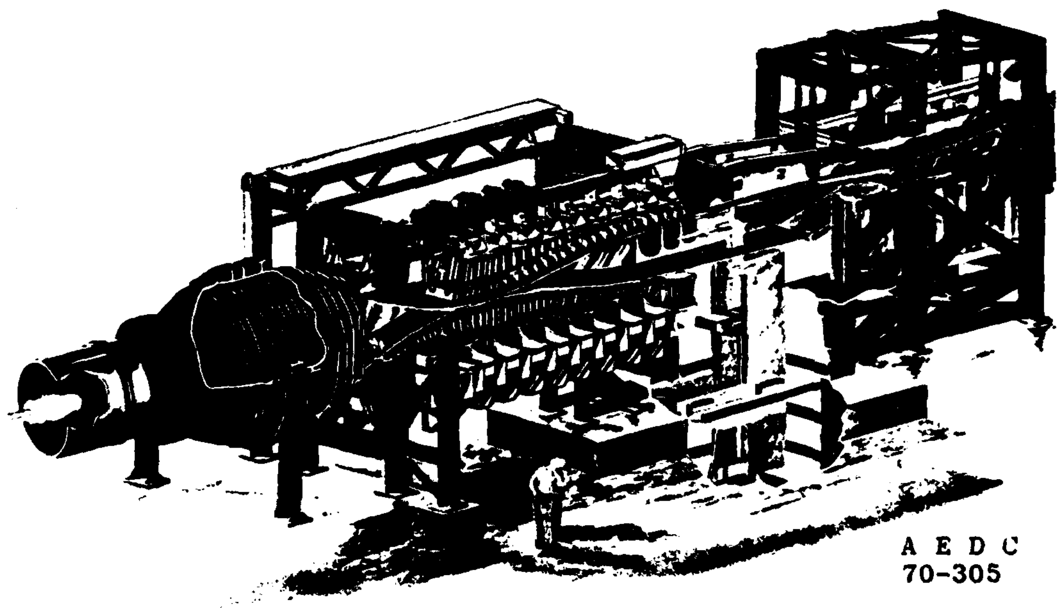
**Thompson, J. W. and Abernethy, R. B. et al., "Handbook Uncertainty in Gas Turbine Measurements." AEDC-TR-73-5 (AD755356), February 1973.

APPENDIX I

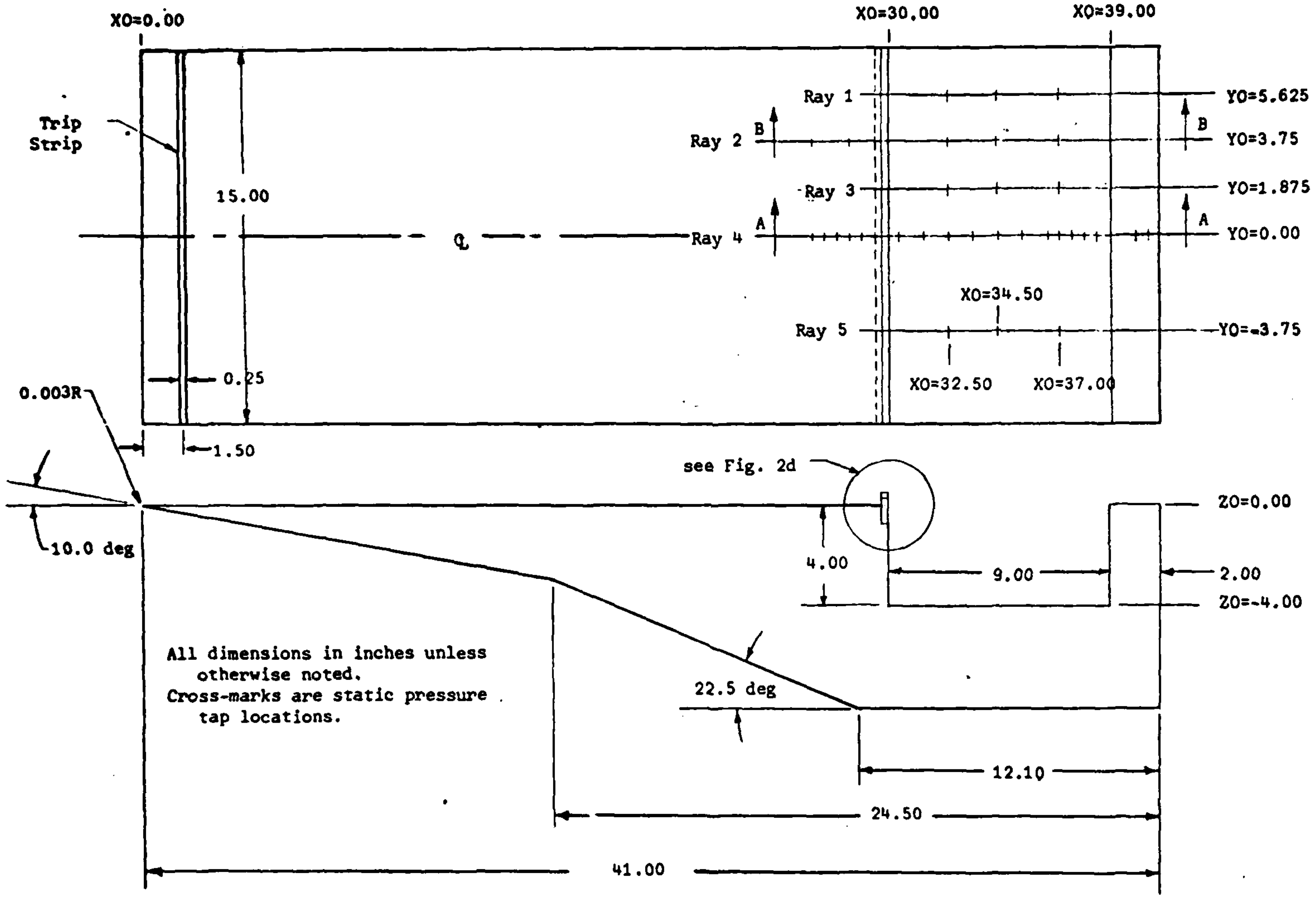
ILLUSTRATIONS




**a. Tunnel assembly**

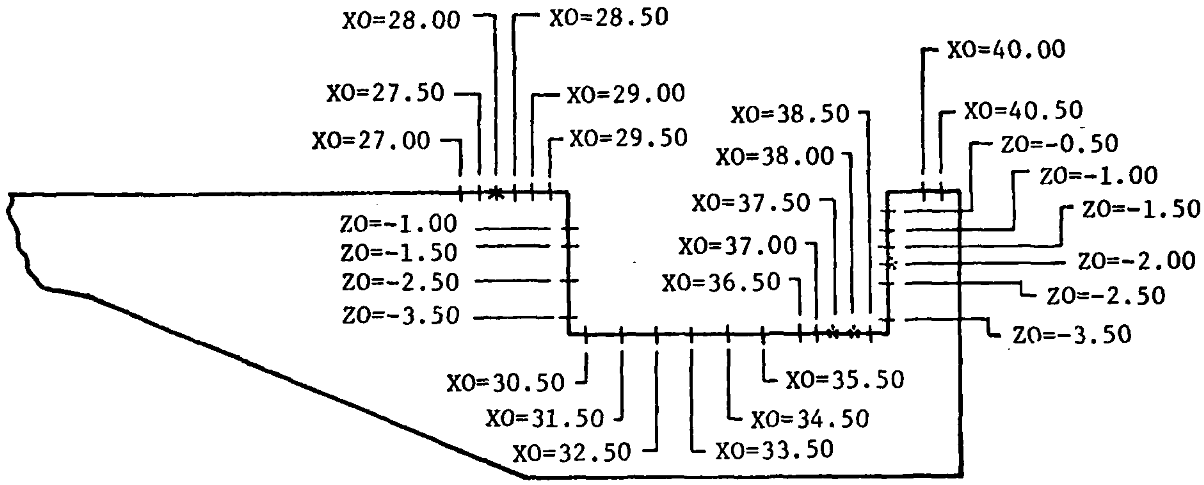



**b. Tunnel test section**
**Fig. 1 Tunnel A**



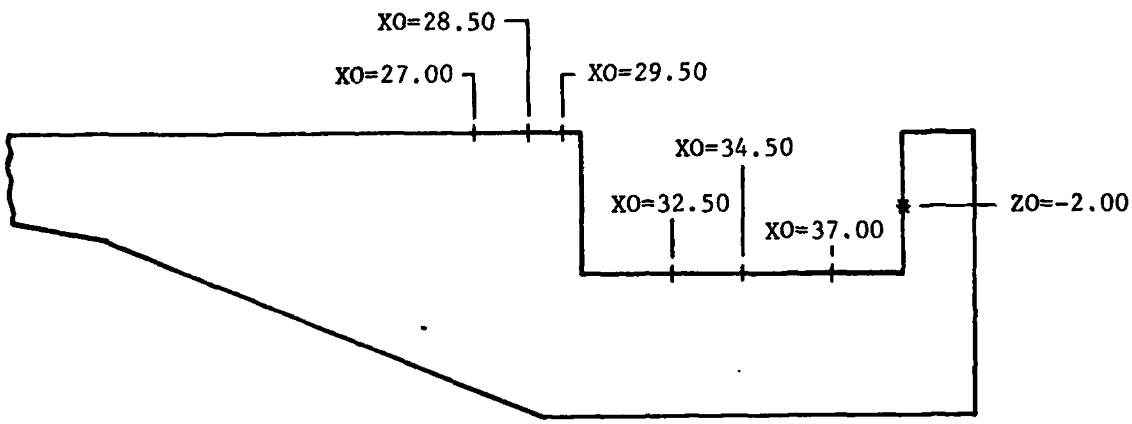

a. Cavity

Figure 2. Cavity Model Details




View A-A

b. Ray 4 Detail (YO=0.00)

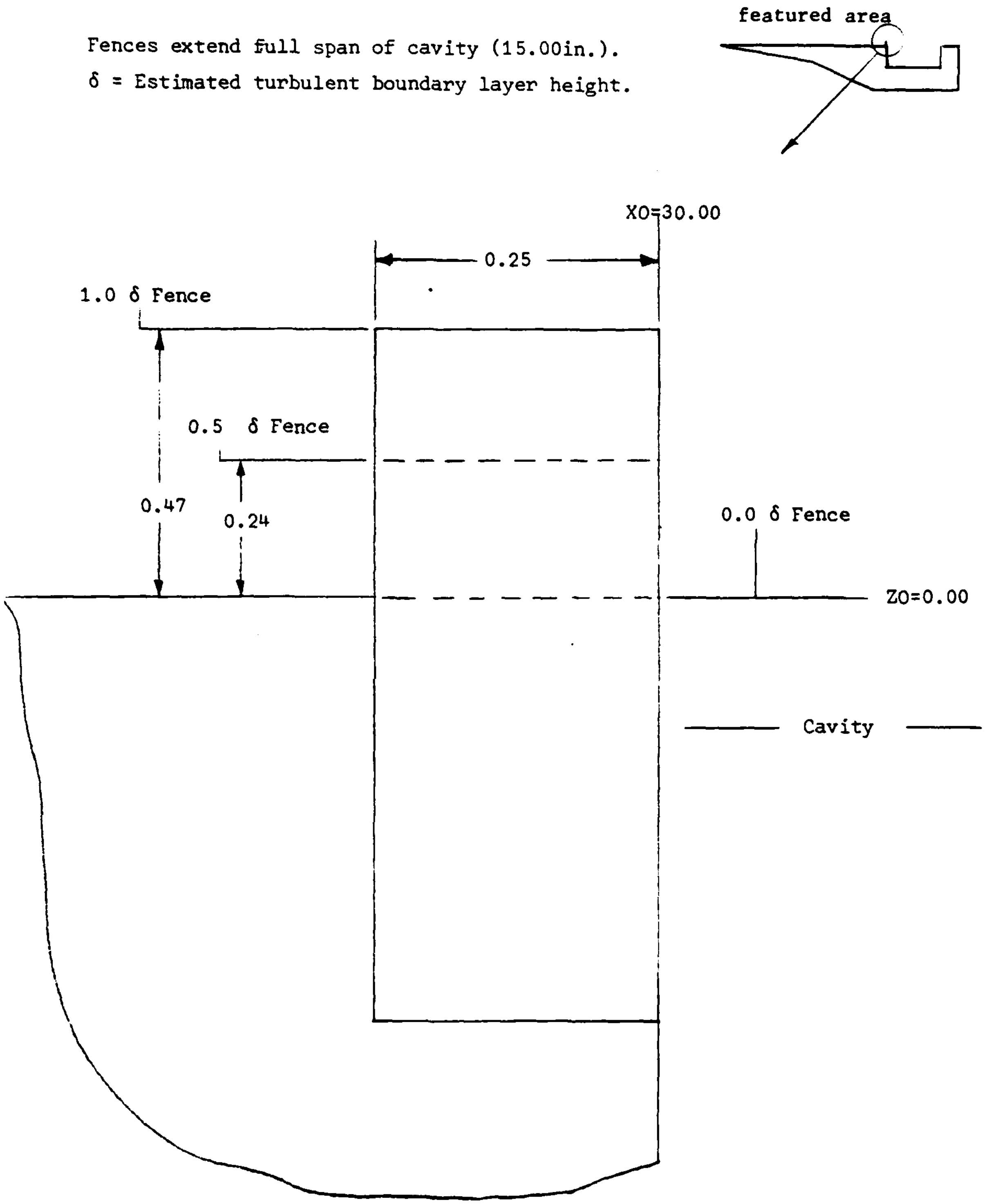



View B-B

c. Ray 2 Detail (YO=3.75)

Cross-marks are static pressure tap locations.
"*" denotes dynamic pressure transducer.
Rays 1, 3, 5 detail given on Fig. 2a.

Figure 2. Continued




d. Enlarged View of Suppression Fence

Figure 2. Concluded

All dimensions in inches unless otherwise noted.
Store sizes relative to 36in.$^2$ cavity cross-section area.
Store shapes are full span of cavity (15.00 in.).

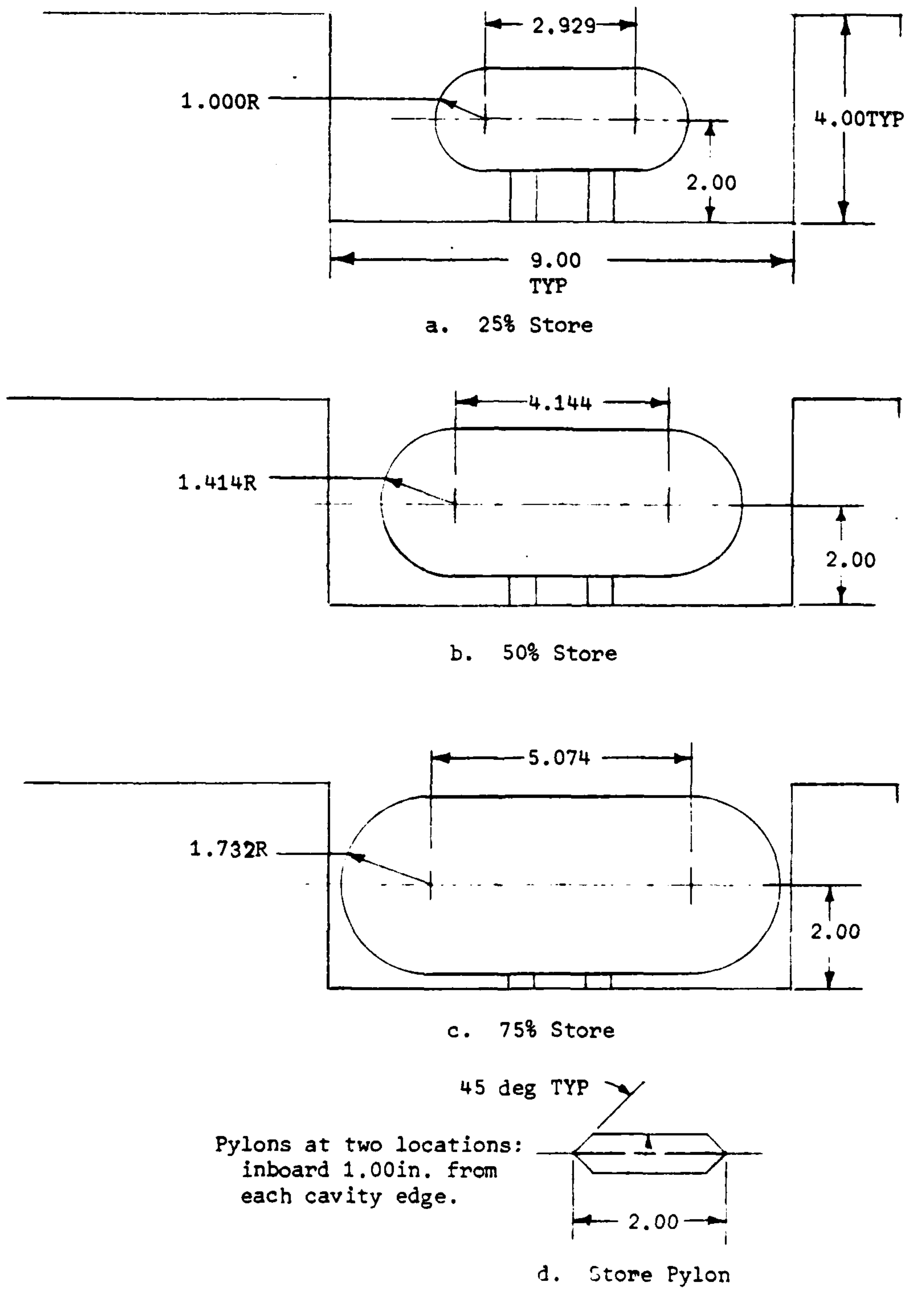



Figure 3. Cavity Store Shapes with Pylon

All dimensions in inches unless othewise noted.

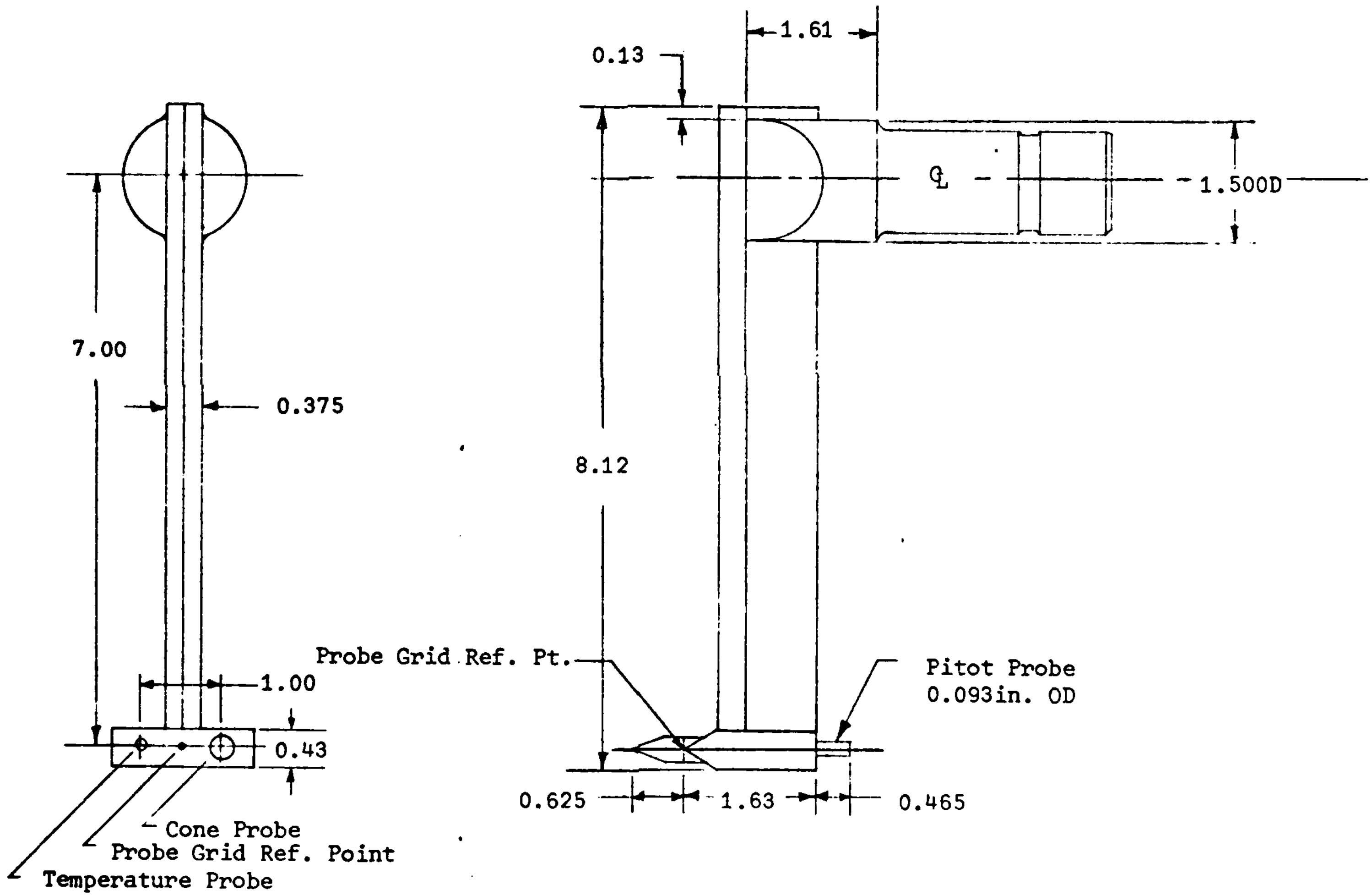
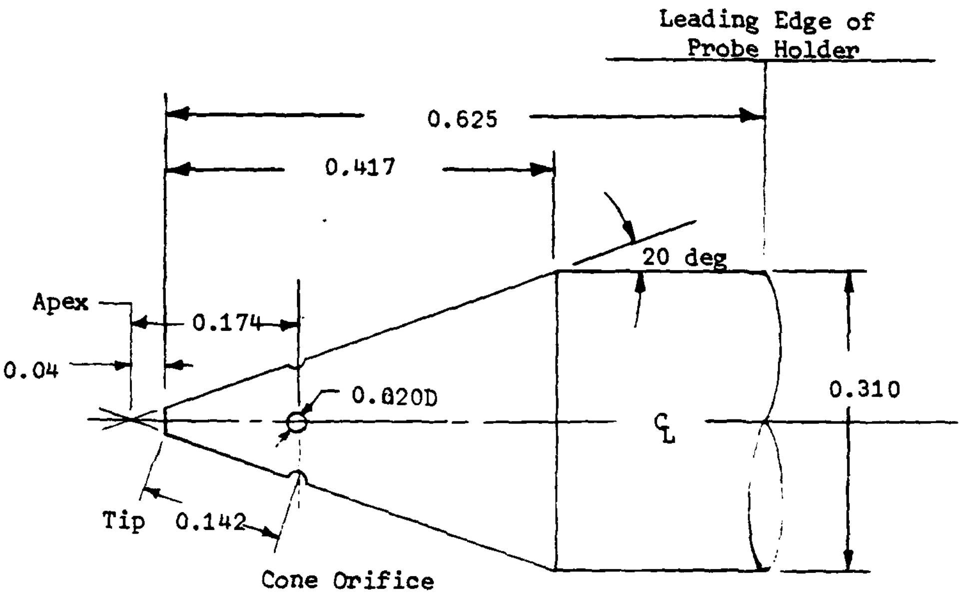



Figure 4. Probe Holder Details




All dimensions in inches
unless otherwise noted.

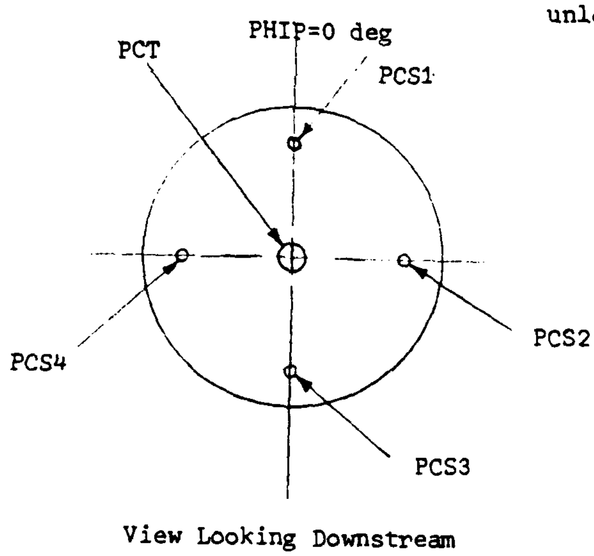



Figure 5. Details of Cone Probe

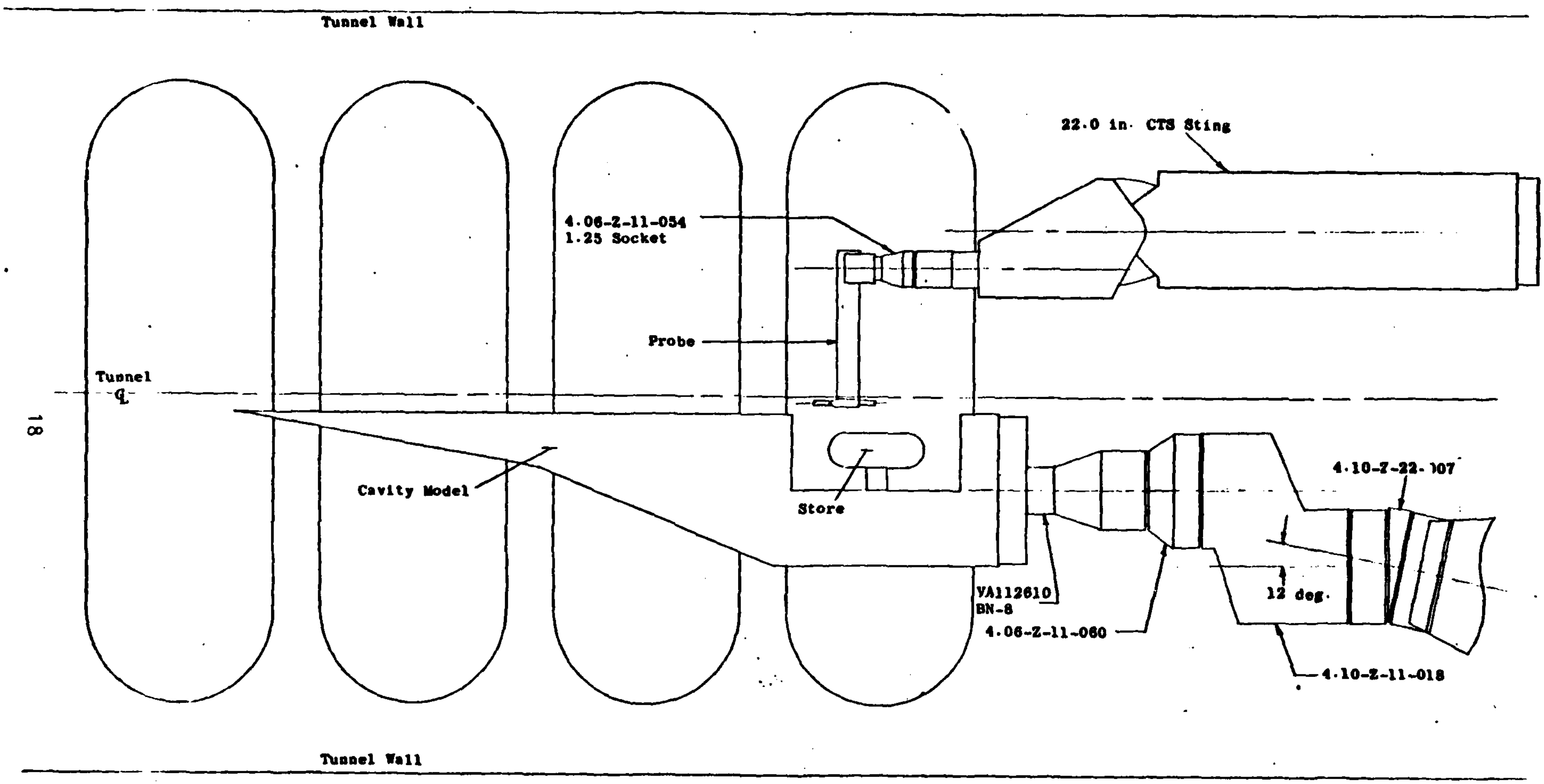
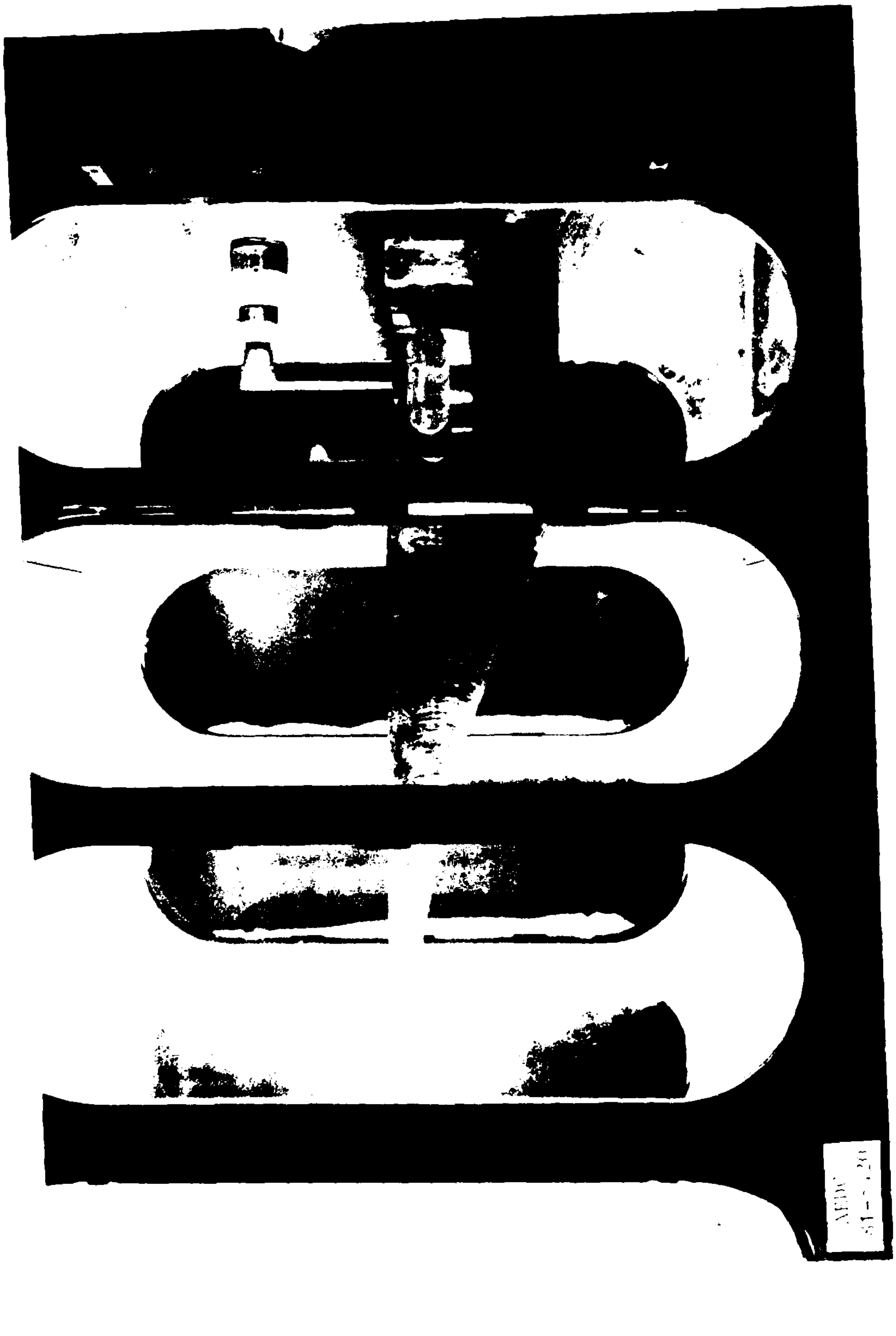



Figure 6. Installation Sketch


AEDC

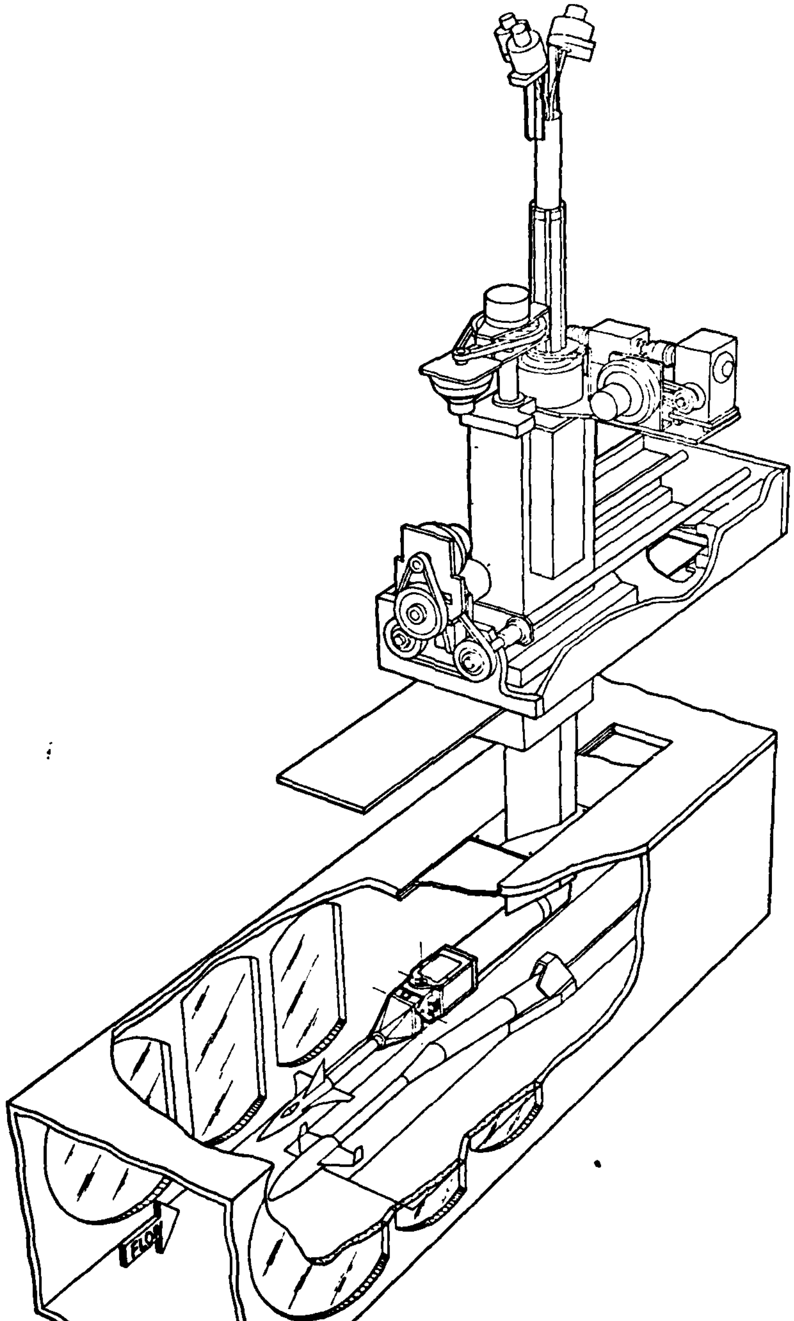
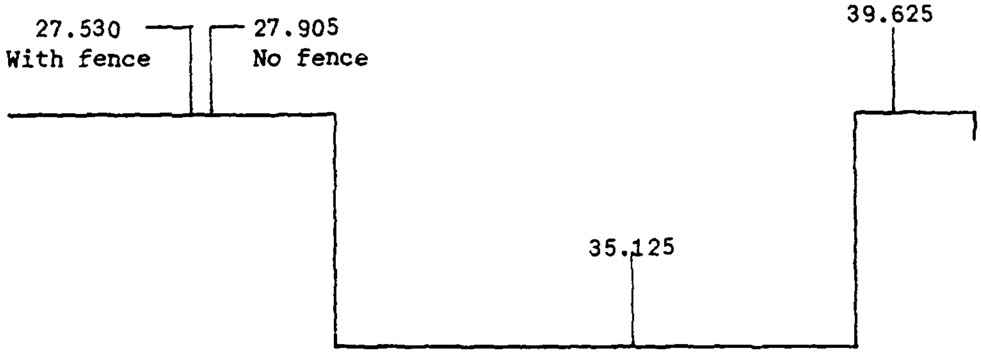


Figure 8. Artist's Conception of the VKF/CTS Installed in Tunnel A




Actual probe tip locations are given by the following since orientations (ALPHAP, YAWP, PHIP) are zero or negligible.

| Cone Probe | Pitot Probe | Temperature Probe |
|---|---|---|
| XPC = X-0.625 | XPP = X+2.095 | XPT = X-0.625 |
| YPC = Y-0.500 | YPP = Y-0.500 | YPT = Y+0.500 |
| ZPC = Z | ZPP = Z | ZPP = Z |

All survey stations have probe grid reference point on model centerline, Y0 = 0.00. Axial locations are for probe grid reference point from leading edge of flat plate, XO = 0.00. Probe grid reference point shown in Figure 4.

Figure 9. Grid Survey Stations

APPENDIX II

TABLES

TABLE 1. Data Transmittal Summary

The following items were transmitted to the Sponsor/User.

Sponsor/User

Mr. J. W. Doran
AFWL/NTSAC
Kirtland AFB, NM 87117

| Item | No. of Copies |
|---|---|
| Final Tabulated Data, Runs 1-20*,+ | 2 (Others: 1 copy) |
| Data Transit Tape+ | 1 |
| Sample Tape Printout+ | 1 |
| Data Transit Tape Format+ | 1 |
| 70mm Schlieren Stills* Roll No. 0052 | 1 Contact Print<br>1 Duplicate Negative |
| 16mm Schlieren Movies: Reel Nos. 4548-4553 | 1 Optical Master<br>1 Work Print* |
| Photographic Data Log | 1 |
| Video Cassette, Runs 1-20 | 1 |
| Model Installation Photographs, 8x10 prints*,+ | 2 (Others: 1 copy) |

Other Data Distribution:

* Mr. L. L. Shaw
AFWAL/FIBE
Wright Patterson AFB, OH 45433

\+ Mr. Alan Ratliff
LMSC
4800 Bradford Blvd.
Huntsville, AL 35807

TABLE 2. Cavity Instrumentation Summary

| Txxx | XO | YO | ZO |
|---|---|---|---|
| 101 | 32.50 | 5.625 | -4.00 |
| 102 | 34.50 | | |
| 103 | 37.00 | | |
| 201 | 27.00 | 3.75 | 0.00 |
| 202 | 38.50 | | |
| 203 | 29.50 | | |
| 204 | 32.50 | | -4.00 |
| 205 | 34.50 | | |
| 206 | 37.00 | | |
| 207A | 39.00 | | -2.00 |
| 301 | 32.50 | 1.875 | -4.00 |
| 302 | 34.50 | | |
| 303 | 37.00 | | |
| 401 | 27.00 | 0.00 | 0.00 |
| 402 | 27.50 | | |
| 403A | 28.00 | | |
| 404 | 28.50 | | |
| 405 | 29.00 | | |
| 406 | 29.50 | | |
| 407 | 30.00 | | -1.00 |
| 408 | | | -1.50 |
| 409 | | | -2.50 |
| 410 | | | -3.50 |

| Txxx | XO | YO | ZO |
|---|---|---|---|
| 411 | 30.50 | 0.00 | -4.00 |
| 412 | 31.50 | | |
| 413 | 32.50 | | |
| 414 | 33.50 | | |
| 415 | 34.50 | | |
| 416 | 35.50 | | |
| 417 | 36.50 | | |
| 418 | 37.00 | | |
| 419A | 37.50 | | |
| 420A | 38.00 | | |
| 421 | 38.50 | | |
| 422 | 39.00 | | -3.50 |
| 423 | | | -2.50 |
| 424A | | | -2.00 |
| 425 | | | -1.50 |
| 426 | | | -1.00 |
| 427 | | | -0.50 |
| 429 | 40.00 | | 0.00 |
| 430 | 40.50 | | 0.00 |
| 501 | 32.50 | -3.75 | -4.00 |
| 502 | 34.50 | | |
| 503 | 37.00 | | |

TABLE 3. CTS Motion Capabilities in Tunnel A

| MOTION | MAXIMUM[1] TRAVEL LIMITS | MAXIMUM[2] RATE OF TRAVEL |
|---|---|---|
| XC | ±20 in. | 1.2 in.-sec$^{-1}$ |
| ZC | ±15 in. | 1.2 in. - sec$^{-1}$ |
| ETAC[3] | ±25 deg | 2.7 deg-sec$^{-1}$ |
| YAWC[3] | ±45 deg | 10.4 deg-sec$^{-1}$ |
| ALPHAC | ±45 deg | 11.7 deg-sec$^{-1}$ |
| PHICB | ±180 deg | 20.5 deg-sec$^{-1}$ |

NOTES:
1. Travel limits are set up for each test as a function of model location in the tunnel and the test requirements.
2. Rates are continuously variable up to the values shown and can be computer controlled to allow all drives to reach a commanded point simultaneously.
3. YAWC and ETAC combine to provide a lateral motion of ±15 in.

CTS Motion Nomenclature

| | |
|---|---|
| ALPHAC | CTS pitch drive, deg |
| ETAC | CTS aft yaw drive, deg |
| PHICB | CTS roll drive, deg |
| XC | CTS axial drive, in. |
| YAWC | CTS forward yaw drive, deg |
| ZC | CTS vertical drive, in. |

## TABLE 4. ESTIMATED UNCERTAINTIES

### a. Basic Measurements

| Parameter Designation | STEADY-STATE ESTIMATED MEASUREMENT* | | | | | | | Range | Type of Measuring Device | Type of Recording Device | Method of System Calibration |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Precision Index ± (S) | | | Bias ±(B) | | Uncertainty ±(B + $t_{95}$S) | | | | | |
| | Percent of Reading | Unit of Measurement | Degree of Freedom | Percent of Reading | Unit of Measurement | Percent of Reading | Unit of Measurement | | | | |
| PT, psia | | 0.007 | 30 | 0.2 | | 0.2%PT + 0.014 | | 15-60 | Bell and Howell Force Balance Pressure Transducer | Analog to Digital (A/D) Converter into Digital Data Acquisition System (DDAS) | In-place application of multiple pressure levels [illegible] a pressure [illegible] device [illegible] |
| TT, °F | | 1.0 | 30 | | 2.0 | | 4.0 | 70-300 | Chromel®-Alumel® Thermocouple | Digital scanner via microprocessor based multiplexer via Fluke digital thermometer | [illegible] NBS conformity [illegible] tation [illegible] |
| **CTS Drives** | | | | | | | | | | | |
| XC, in | | 0.0040 | 30 | | 0.0021 | | 0.0101 | ±20 | Potentiometer | Digital scanner via A/D converter | [illegible] |
| ZC, in. | | 0.0056 | 30 | | 0.0004 | | 0.0116 | ±15 | | | |
| PHICB, deg | | 0.0877 | 30 | | 0+ | | 0.1754 | N/A | | | |
| ALPHAC, deg | | 0.0295 | 30 | | 0.0102 | | 0.0692 | ±45 | | | |
| YAWC, deg | | 0.0204 | 30 | | 0+ | | 0.0408 | N/A | | | |
| LIAC, deg | | 0.0148 | 30 | | 0+ | | 0.0296 | N/A | | | |
| ALPHAC, deg (cavity) | | 0.005 | 30 | | 0.05 | | 0.06 | ±4 | Shaevitz Servo inclinometer | | Comparison with [illegible] |
| YAWC, deg (cavity) | | 0.25 | 30 | | 0+ | | 0.30 | ±0.5 | Precision inclinometer gage reading | Manual | Fixed length [illegible] |
| Txxx, psia | | 0.0015 | 30 | 0.15 | | 0.15%Txxx + 0.0030 | | 0-15 | Bell and Howell differential capacitance pressure transducer | A/D Converter into DDAS | [illegible] the standard [illegible] |
| PCS1-PCS4, PCT, PPT, psia | | 0.003 | 30 | | 0.005 | | 0.011 | 0-15 | Kistler Force Balance Pressure Transducer | | |
| TPT, °F | | 1.0 | 30 | | 2.0 | | 4.0 | 70-300 | Chromel®-Alumel® Thermocouple | Fluke digital thermometer into [illegible] Scanner into DDAS | [illegible] |
| TxxxA, dB | | 0.5 | 30 | | 0+ | | 1.0 | 105-180 | Gulton microphone | RMS voltmeter into A/D converter into DDAS | [illegible] & Kjaer [illegible] phone calibrator [illegible] standards [illegible] |

*Thompson, J. W. and Abernethy, R. B. et al. "Handbook Uncertainty in Gas Turbine Measurements," AEDC-TR-73-5 (AD 755356), February 1973.

+Assumed to be zero

[illegible] (2/81)

TABLE 4. Continued

a. Concluded

| Parameter Designation | STEADY-STATE ESTIMATED MEASUREMENT* | | | | | | | Range | Type of Measuring Device | Type of Recording Device | Method of [illegible] Calibration |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Precision Index (S) | | | Bias (B) | | Uncertainty ±(B + $t_{95}$S) | | | | | |
| | Percent of Reading | Unit of Measurement | Degree of Freedom | Percent of Reading | Unit of Measurement | Percent of Reading | Unit of Measurement | | | | |
| DYNAMIC PRESSURE MEASUREMENT, dB | | 0.5 | 30 | | $0^{+}$ | | 1.0 | 105-180 | Gulton microphone | Bell & Howell VR-3700 Analog magnetic tape machine | Bruel & K[illegible] Piston[illegible] calibrated at s[illegible] lab |

*Thompson, J. W. and Abernethy, R. B. et al. "Handbook Uncertainty in Gas Turbine Measurements." AEDC-TR-73-5 (AD 755356), February 1973.

+Assumed to be zero

TABLE 4. Concluded
b. Calculated Parameters

| Parameter Designation | STEADY-STATE ESTIMATED MEASUREMENT[a] Precision Index (S) | | | Bias (B) | | Uncertainty $\pm(B + t_{95}S)$ | | M/RE$\times10^{-6}$ |
|---|---|---|---|---|---|---|---|---|
| | Percent of Reading | Unit of Measurement | Degree of Freedom | Percent of Reading | Unit of Measurement | Percent of Reading | Unit of Measurement | |
| M | | 0.008 | | | $0^+$ | | 0.016 | 3/3.0 |
| P, psia | | 0.0060 | | | 0.0010 | | 0.0130 | 3/3.0 |
| Q, psia | | 0.0214 | | | 0.0064 | | 0.0492 | 3/3.0 |
| PT2, psia | | 0.0422 | | | 0.0122 | | 0.0966 | 3/3.0 |
| RE$\times10^{-6}$, ft$^{-1}$ | | 0.0655 | | | 0.1287 | | 0.2597 | 3/3.0 |
| X, XPC, XPP, XPT | | 0.010 | | | 0.004 | | 0.024 | 3/3.0 |
| Y, YPC, YPP, YPT | | 0.018 | | | $0^+$ | | 0.036 | |
| Z, ZPC, ZPP, ZPT | | 0.015 | | | 0.004 | | 0.034 | |
| ALPHAP | | 0.046 | | | 0.010 | | 0.102 | 3/3.0 |
| YAWP | | 0.025 | | | $0^+$ | | 0.050 | |
| PHIP | | 0.088 | | | $0^+$ | | 0.176 | |

[a]Abernethy, R. B. et al. and Thompson, J. W. "Handbook Uncertainty in Gas Turbine Measurements." AEDC-TR-73-5 (AD 755356), February 1973.
[+]Assumed to be zero

TABLE 5. Test Summary

$M = 3$, $RE = 3.0 \times 10^6 ft^{-1}$, $ALPHA = 0.0$ deg

Configuration: Cavity Flow Model (No Probe)

| STORE[1] | FENCE[2] | RUN |
|---|---|---|
| 0 | 0 | 12 |
| 0 | 1 | 11 |
| 25 | 0 | 1,20 |
| 25 | 1 | 6 |
| 50 | 1 | 16 |
| - | - | 5[3] |

Configuration: Cavity Flow Model (With Probe)

| STORE[1] | FENCE[2] | SURVEY STATION[4] | | |
|---|---|---|---|---|
| | | FWD | MID | AFT |
| 0 | 0 | 15 | 14 | 13 |
| 25 | 0 | 4 | 3 | 2 |
| 25 | 1 | 9,10 | 8 | 7 |
| 50 | 1 | 19 | 18 | 17 |

NOTES:

1. STORE - Percent of cavity cross-section area occupied by store shape. Total area = 36.0 in.$^2$
2. FENCE - Suppression fence height normalized by estimated boundary layer thickness. $\delta = 0.47$ in.
3. RUN 5 - Probe calibration in free-stream. ALPHAP = -5.0 to 5.0 deg
4. SURVEY STATION - Location of probe grid survey in inches from model leading edge.
   FWD - 27.905 in. (no fence); 27.530 in. (with fence)
   MID - 35.125 in.
   AFT - 39.625 in.

# APPENDIX III

## SAMPLE TABULATED DATA

VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
AFWL CAVITY FLOW

DATE COMPUTED 9-NOV-81
TIME COMPUTED 14:32:20
DATE RECORDED 27-OCT-81
TIME RECORDED 5:40:30
PROJECT NUMBER V A-22

PAGE= 1 GRID 1- 1

| RUN | CODE | M | PT | TT | Q | P | PT2 | T | RE |
|---|---|---|---|---|---|---|---|---|---|
| 13 | 6 | 3.01 | 18.76 | 539.7 | 3.191 | 0.503 | 6.107 | 191.9 | 0.291E+07 |

| CONFIG | STOPE | FENCE | TRIP | DATA TYPE |
|---|---|---|---|---|
| CAVITY FLOW MODEL | 0 | 0.0 | .0160 | P+PW+A |

*CAVITY MODEL* -ATTITUDE- — TUNNEL CONDITIONS — * *PROBE* * — POSITIONS —

| PR | ALPHAC | YAWC | PT | TT | Q | P | PT2 | X | Y | Z | ALPHAP | YAWP | PHIP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.01 | 0.00 | 18.76 | 539.7 | 3.191 | 0.503 | 6.1066 | 39.6234 | -0.0096 | 0.2535 | -0.0185 | -0.0256 | -0.0118 |
| 2 | 0.01 | 0.00 | 18.75 | 539.7 | 3.189 | 0.503 | 6.1042 | 39.6234 | -0.0091 | 0.3791 | -0.0200 | -0.0241 | -0.0118 |
| 3 | 0.01 | 0.00 | 18.75 | 539.7 | 3.189 | 0.503 | 6.1030 | 39.6235 | -0.0096 | 0.5015 | -0.0189 | -0.0256 | -0.0118 |
| 4 | 0.01 | 0.00 | 18.75 | 539.7 | 3.189 | 0.503 | 6.1042 | 39.6234 | -0.0101 | 0.6285 | -0.0200 | -0.0270 | -0.0170 |
| 5 | 0.01 | 0.00 | 18.76 | 539.7 | 3.191 | 0.503 | 6.1078 | 39.6232 | -0.0091 | 0.7537 | -0.0200 | -0.0241 | -0.0118 |
| 6 | 0.01 | 0.00 | 18.75 | 539.7 | 3.189 | 0.503 | 6.1042 | 39.6234 | -0.0091 | 0.8768 | -0.0196 | -0.0241 | -0.0118 |
| 7 | 0.01 | 0.00 | 18.76 | 539.7 | 3.191 | 0.503 | 6.1066 | 39.6234 | -0.0100 | 1.0025 | -0.0196 | -0.0267 | -0.0118 |
| 8 | 0.01 | 0.00 | 18.77 | 539.7 | 3.192 | 0.503 | 6.1089 | 39.6234 | -0.0106 | 1.1265 | -0.0189 | -0.0285 | -0.0118 |

Sample 1: Tunnel Conditions and Position Data

VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
AFWL CAVITY FLOW

DATE COMPUTED 9-NOV-81
TIME COMPUTED 14:32:20
DATE RECORDED 27-OCT-81
TIME RECORDED 5:40:30
PROJECT NUMBER V A-22

PAGE= 2 GRID 1- 1

| RUN | CODE | M | PT | TT | Q | P | PT2 | T | RE |
|---|---|---|---|---|---|---|---|---|---|
| 13 | 6 | 3.01 | 18.76 | 539.7 | 3.191 | 0.503 | 6.107 | 191.9 | 0.291E+07 |

| CONFIG | STORE | FENCE | TRIP | DATA TYPE |
|---|---|---|---|---|
| CAVITY FLOW MODEL | 0 | 0.0 | .0160 | P+PW+A |

* CAVITY MODEL STATIC PRESSURES *
(RATIOED TO P)

| PN | T101 | T102 | T103 | T201 | T202 | T203 | T204 | T205 | T206 | T301 | T302 | T303 | T401 | T402 | T404 | T405 | T406 | T407 | T408 | T409 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.015 | 1.047 | 1.109 | 1.001 | 1.015 | 1.367 | 1.033 | 1.027 | 1.134 | 1.132 | 1.166 | 1.070 | 1.043 | 1.049 | 1.058 | 1.059 | 1.053 | 1.323 | 1.326 | 1.353 |
| 2 | 1.016 | 1.049 | 1.109 | 1.002 | 1.017 | 1.367 | 1.032 | 1.026 | 1.133 | 1.131 | 1.167 | 1.068 | 1.045 | 1.049 | 1.058 | 1.060 | 1.054 | 1.327 | 1.328 | 1.357 |
| 3 | 1.014 | 1.048 | 1.109 | 1.001 | 1.016 | 1.368 | 1.032 | 1.027 | 1.133 | 1.131 | 1.166 | 1.067 | 1.044 | 1.049 | 1.059 | 1.060 | 1.054 | 1.324 | 1.327 | 1.358 |
| 4 | 1.014 | 1.047 | 1.110 | 1.001 | 1.017 | 1.367 | 1.032 | 1.026 | 1.133 | 1.131 | 1.168 | 1.068 | 1.045 | 1.049 | 1.058 | 1.060 | 1.054 | 1.327 | 1.328 | 1.357 |
| 5 | 1.015 | 1.047 | 1.107 | 1.000 | 1.016 | 1.366 | 1.032 | 1.027 | 1.132 | 1.130 | 1.167 | 1.070 | 1.044 | 1.048 | 1.058 | 1.059 | 1.053 | 1.323 | 1.328 | 1.354 |
| 6 | 1.017 | 1.049 | 1.110 | 1.002 | 1.017 | 1.367 | 1.035 | 1.029 | 1.134 | 1.131 | 1.169 | 1.073 | 1.045 | 1.049 | 1.058 | 1.061 | 1.054 | 1.325 | 1.328 | 1.356 |
| 7 | 1.017 | 1.047 | 1.109 | 1.002 | 1.017 | 1.367 | 1.034 | 1.030 | 1.134 | 1.130 | 1.169 | 1.073 | 1.045 | 1.049 | 1.058 | 1.059 | 1.053 | 1.321 | 1.325 | 1.354 |
| 8 | 1.016 | 1.048 | 1.108 | 1.002 | 1.016 | 1.366 | 1.033 | 1.028 | 1.133 | 1.130 | 1.167 | 1.070 | 1.044 | 1.048 | 1.057 | 1.060 | 1.053 | 1.324 | 1.327 | 1.356 |

| PN | T410 | T411 | T412 | T413 | T414 | T415 | T416 | T417 | T418 | T421 | T422 | T423 | T425 | T426 | T427 | T429 | T430 | T501 | T502 | T503 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.399 | 1.299 | 1.215 | 1.177 | 1.168 | 1.205 | 1.226 | 1.250 | 1.240 | 1.331 | 1.218 | 1.056 | 1.071 | 1.044 | 1.053 | 1.163 | 0.919 | 1.052 | 1.070 | 1.129 |
| 2 | 1.404 | 1.302 | 1.217 | 1.178 | 1.170 | 1.206 | 1.227 | 1.252 | 1.241 | 1.334 | 1.222 | 1.063 | 1.068 | 1.043 | 1.048 | 1.332 | 0.804 | 1.051 | 1.069 | 1.129 |
| 3 | 1.404 | 1.301 | 1.217 | 1.179 | 1.169 | 1.204 | 1.226 | 1.252 | 1.243 | 1.333 | 1.220 | 1.062 | 1.066 | 1.042 | 1.048 | 1.579 | 0.701 | 1.051 | 1.068 | 1.128 |
| 4 | 1.407 | 1.302 | 1.217 | 1.177 | 1.168 | 1.206 | 1.229 | 1.255 | 1.244 | 1.335 | 1.224 | 1.063 | 1.066 | 1.042 | 1.047 | 1.829 | 0.769 | 1.051 | 1.068 | 1.128 |
| 5 | 1.405 | 1.301 | 1.215 | 1.178 | 1.169 | 1.204 | 1.225 | 1.251 | 1.241 | 1.332 | 1.222 | 1.064 | 1.069 | 1.044 | 1.051 | 2.182 | 1.259 | 1.053 | 1.070 | 1.130 |
| 6 | 1.405 | 1.302 | 1.217 | 1.178 | 1.170 | 1.206 | 1.227 | 1.253 | 1.243 | 1.335 | 1.225 | 1.065 | 1.074 | 1.046 | 1.053 | 2.300 | 1.884 | 1.054 | 1.071 | 1.131 |
| 7 | 1.404 | 1.301 | 1.216 | 1.178 | 1.168 | 1.205 | 1.226 | 1.251 | 1.241 | 1.331 | 1.221 | 1.066 | 1.075 | 1.048 | 1.056 | 2.172 | 2.383 | 1.053 | 1.070 | 1.132 |
| 8 | 1.404 | 1.301 | 1.216 | 1.178 | 1.167 | 1.204 | 1.226 | 1.254 | 1.243 | 1.334 | 1.224 | 1.063 | 1.069 | 1.045 | 1.051 | 1.838 | 2.355 | 1.051 | 1.070 | 1.130 |

Sample 2: Cavity Surface Pressure Data

DATE COMPUTED 9-NOV-81
TIME COMPUTED 14:32:20
DATE RECORDED 27-OCT-81
TIME RECORDED 5:40:30
PROJECT NUMBER V A-22

VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
AFWL CAVITY FLOW

PAGE= 3 GPID 1- 1

| RUN | CODE | M | PT | TT | Q | P | PT2 | T | RE |
|---|---|---|---|---|---|---|---|---|---|
| 13 | .6 | 3.01 | 18.76 | 539.7 | 3.191 | 0.503 | 6.107 | 191.9 | 0.291E+07 |

| CONFIG | STORE | FENCE | TRIP | DATA TYPE |
|---|---|---|---|---|
| CAVITY FLOW MODEL | 0 | 0.0 | .0160 | P+PW+A |

* * CAVITY MODEL ACOUSTIC GAUGES * *
(SOUND PRESSURE LEVEL,DB)

| PN | T207A | T403A | T419A | T420A | T424A |
|---|---|---|---|---|---|
| 1 | 150.76 | 120.22 | 145.73 | 131.22 | 144.65 |
| 2 | 150.80 | 120.38 | 145.78 | 131.26 | 144.75 |
| 3 | 150.80 | 120.22 | 145.73 | 131.26 | 144.70 |
| 4 | 150.85 | 120.38 | 145.78 | 131.22 | 144.60 |
| 5 | 150.78 | 120.38 | 145.73 | 131.22 | 144.65 |
| 6 | 150.67 | 120.22 | 145.63 | 131.22 | 144.60 |
| 7 | 150.74 | 120.22 | 145.73 | 131.26 | 144.79 |
| 8 | 150.76 | 120.38 | 145.78 | 131.26 | 144.70 |

* RELATIVE PROBE POSITIONS *

| CONE | | | PITOT | | | TEMPERATURE | | |
|---|---|---|---|---|---|---|---|---|
| XPC | YPC | ZPC | XPP | YPP | ZPP | XPT | YPT | ZPT |
| 38.998 | -0.510 | 0.254 | 41.718 | -0.510 | 0.254 | 38.998 | 0.490 | 0.254 |
| 38.998 | -0.509 | 0.379 | 41.718 | -0.509 | 0.379 | 38.998 | 0.491 | 0.379 |
| 38.999 | -0.510 | 0.505 | 41.719 | -0.510 | 0.505 | 38.999 | 0.490 | 0.505 |
| 38.998 | -0.510 | 0.629 | 41.718 | -0.510 | 0.629 | 38.998 | 0.490 | 0.629 |
| 38.998 | -0.509 | 0.754 | 41.718 | -0.509 | 0.754 | 38.998 | 0.491 | 0.754 |
| 38.998 | -0.509 | 0.877 | 41.718 | -0.509 | 0.877 | 38.998 | 0.491 | 0.877 |
| 38.998 | -0.510 | 1.003 | 41.718 | -0.510 | 1.003 | 38.998 | 0.490 | 1.003 |
| 38.998 | -0.511 | 1.127 | 41.718 | -0.511 | 1.127 | 38.998 | 0.489 | 1.127 |

* PROBE PARAMETERS *

| PN | PCS1 | PCS2 | PCS3 | PCS4 | PCSA | PCT | PCSA/PCT | PCT/PT2 | MC | DPP/PCT | DPY/PCT | PPT | PPT/PT2 | MP | TPT | TPT/TT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.764 | 0.717 | 0.662 | 0.788 | 0.733 | 1.252 | 0.585 | 0.205 | 1.273 | 0.082 | -0.057 | 0.254 | 0.042 | 0.000 | 507.7 | 0.978 |
| 2 | 0.824 | 0.774 | 0.711 | 0.843 | 0.788 | 1.906 | 0.413 | 0.312 | 1.692 | 0.059 | -0.036 | 0.239 | 0.039 | 0.000 | 509.7 | 0.978 |
| 3 | 0.929 | 0.877 | 0.825 | 0.944 | 0.894 | 2.797 | 0.320 | 0.458 | 2.142 | 0.037 | -0.024 | 0.206 | 0.034 | 0.000 | 517.7 | 0.978 |
| 4 | 1.073 | 1.024 | 0.997 | 1.096 | 1.048 | 4.016 | 0.261 | 0.658 | 2.611 | 0.019 | -0.018 | 0.179 | 0.029 | 0.000 | 523.7 | 0.978 |
| 5 | 1.191 | 1.170 | 1.184 | 1.244 | 1.197 | 5.182 | 0.231 | 0.848 | 2.981 | 0.001 | -0.014 | 0.174 | 0.028 | 0.000 | 524.7 | 0.978 |
| 6 | 1.266 | 1.285 | 1.355 | 1.361 | 1.317 | 5.816 | 0.226 | 0.953 | 3.052 | -0.015 | -0.013 | 0.169 | 0.028 | 0.000 | 521.7 | 0.978 |
| 7 | 1.299 | 1.346 | 1.462 | 1.426 | 1.383 | 6.064 | 0.228 | 0.993 | 3.024 | -0.027 | -0.013 | 0.159 | 0.026 | 0.000 | 519.7 | 0.978 |
| 8 | 1.316 | 1.384 | 1.528 | 1.465 | 1.423 | 6.197 | 0.230 | 1.014 | 3.000 | -0.034 | -0.013 | 0.148 | 0.024 | 0.000 | 518.7 | 0.978 |

Sample 3: Cavity Acoustic and Probe Parameter Data